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FIELD - LAB CORRELATION
for
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by

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TARGET DETECTION IN THE REAL WORLD
AND FROM PHOTOGRAPHIC PROJECTIONS IN THE LABORATORY -
A CORRELATIONAL STUDY OF THE VALIDITY OF
PHOTO SIMULATION

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This report summarizes a comparison of target acquisition behavior by observers responding to projected 4-color photographic slides with the behavior of comparable observers responding to the real world environment at the time the photographs were taken. Two test sites were employed for these ground-to-ground target detection studies - one a mountain woodland with a dirt road twisting through it, and the other an open meadow upon which occasional trees and bushes had grown. Both sites have ample leaf growth for partial concealment

cont. of three camouflaged static military targets--all carefully positioned at the extreme end of each site, namely a tank, howitzer and a 2 1/2 ton truck. One set of observers (O's) viewed the targets in the field from a near post (250 meters); a second set was located at an intermediate distance (500 meters); and a third at a far post (1000 meters). All O's, checked for acuity (minimum 20/20) and color normalcy, served only once in the field. The same was true in the laboratory where twice as many O's were required, since two screens were used: opaque or front view and translucent or rear view. In the laboratory, as in the field, O's working one at a time, were exposed to a field or more than 90^{0} or a 12' x 4' panoramic display. Their task: to detect and identify all targets as quickly as possible with a 3 minute maximum search time. Analysis of the results yielded high correlations (average + .80) between the responses of 100 subjects at six posts with the same number of subjects for the six posts in front projection and another hundred subjects for the six posts in front projection and another hundred subjects in the same series of rear projected scenes. The conclusion is justified that 35 mm slides are a valid simulation of the real world. That is, the two-dimensional display produces the same behaviors (hits, misses, false detects, times to detect and identify) as was found in the field. Therefore, photo simulation can be validly employed in testing the efficacy of various camouflage treatments of targets; thus avoiding the necessity of taking observers to the field. No difference was found between front and rear projection screens. Nor is the simulation less effective at greater distances (half a mile) than when targets are nearby. Finally, correlations for per cent of targets detected are equal in magnitude to those for times to detect, so these two measures provide equally valid estimates of the difficulty of target acquisition.

In view of the robust positive correlations found (well beyond the .1% level of confidence), the recommendation is advanced that this method be employed as a sensitive and practical measure of future attempts to improve concealment of equipment or personnel.

FOREWORD AND ACKNOWLEDGEMENTS

This task effort was performed by the Virginia Military Institute's Research Laboratory (VMIRL) in and near Lexington, Virginia, and was supported by the U.S. Army Mobility Equipment Research and Development Center (MERDC), Fort Belvoir, Virginia, under Contract #DAAG53-76-C-0060. The initial impetus was provided by Messrs. Donald Dinger and Laurence Gale of MERDC in reflective conference with Dr. D. Rae Carpenter of VMIRL. The contributions of these men are gratefully acknowledged. Mr. Albert Perri of MERDC, with the assistance of Mr. Ronald Johnson, effectively filled the position of technical monitor with Mr. Blevins as contract officer. For VMIRL, Dean Foster and Paul School served as co-directors of the research. Statistical assistance was provided by David Bolen and technical aid on camouflaged target selection and placement was advanced by Major Donald Cummings and his staff of the VMI armored Army ROTC command. We note, too, the willing assistance of more than three hundred members of the Corps of Cadets of the VMI who volunteered as subjects during the field and laboratory phases of this investigation. They were indispensable to its successful completion. For aiding in their participation our thanks goes to Colonel William Buchanan, Professor of Military Science and Commandant of Cadets. We are indebted, too, for his approval for the use of field equipment so vital to the study reported herein.

This effort prompted about a dozen pilot studies each of which shed light upon the experimental focus or overweening research objectives. In effect, these sub-studies helped to indicate the direction which future investigations in this particular realm should logically take. The data presented are indeed convincing in that they support the case that valid simulation is readily possible with conventional photographic methods. Nevertheless, the effectiveness and efficiency of such procedures shall certainly be enhanced by significant refinements from the several subsidiary clues identified in these pilot experiments.

The present research had as its goal maximum verisimilitude, but this goal incorporated constraints of practicality and general accessibility and many choices had to be made from among numerous alternatives. These choices necessarily affected all major independent variables. They were made after thorough and most reasonable assessment of each alternative in a conjunctive effort between MERDC and VMIRL personnel. For example, such considerations as the use of motion pictures or TV, rather than stills, various observer to target elevations, use of more common targets, selection and instruction of trained vs. untrained observers, use of a lesser number of targets per scene, a new means of scoring and analysis of responses as well as inclusion of different types of screens, viewing angles, projection equipment, distances, terrains, seasons, etc., etc. All choices were made by amicable consensus--all in accord with government need, yet attentive to the states of the arts available and the options open to us.

The final methods selected reflect the product of this merging of our respective conceptualizations to produce a rational approximation of the ideal for achieving the research objective in question.

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1.0 Objective

The primary purpose of this study was to determine if observers can detect and identify camouflaged targets reproduced on projected photographic transparencies with the same accuracy that comparable observers were able to do in the real world at the time the photographs were made. Only a significantly high degree of correlation between field and laboratory observations would justify the conclusion that such a simulation technique is valid.

1.1. Background

In warfare, a prime objective is to be able to conceal one's troops, weapons, and other equipment from enemy view at all times and in all environments. But no concealment treatment, short of burial, is universally effective. Furthermore, diverse theatres of action call for different techniques of concealment. Illustratively, consider concealing a target in such varied environments as jungle, seashore, desert, and snow. Alternative approaches designed to achieve a blending or camouflage effectiveness can be advanced, but the testing of such alternate treatments using observers in the diverse fields is costly of time and effort. But if the field can be brought indoors by the relatively simple expedient of photography, where observers can most easily respond to the camouflage treatments, then much of the time and effort can be saved. In brief, this is the rationale underlying these experiments.

And of no small consequences are the permanence and standard qualities of photographic simulation. The real world can quickly cloud over, darken, or become brown, green, white, or hazy. The film. on the other hand, can capture and "freeze" for us a repr^sentative sample of the scene in each condition so that we can subject it to different types of experimental scrutiny at our leisure.

Others have employed photo simulations, models, and combinations thereof. But no one, to our knowledge, has employed panoramic displays of the type employed in these experiments. This belief is substantiated by a comprehensive search of the literature which was effected at the outset. It is summarized in Appendix I. The literature search is also reflected in the references at the outset. It is throughout this report.

Of great preliminary value were the pilot studies summarized in Appendix II. Each of these studies addresses a specific question relating to technique or experimental procedure, selection of equipment, observer screening and calibration, site selection, and measurement of target properties--in the field and in the laboratory.

1.2. Hypotheses

The problem statement or general research objectives delineated in 1.0 (above) provide the basis for the derivation of more specific experimental hypotheses to be examined in this study.

Let us accept as factual that in any terrain when several semi-concealed targets, each with different properties, are located that some will be more visible than others. It follows then that a continuum is formed by such targets ranging from completely invisible at the one extreme to completely visible at the other. If validity is to be achieved then the very same degree of visibility in the field should produce the same degree of visibility in the laboratory. The only way such visibility can be measured in either instance is with human observers (O's). More specifically:

1. If a given target is easily detected by O's in the real world it will also be equally detected by O's responding to an accurate reproduction of that world in the laboratory, and vice versa.

2. The percentages of O's who detect given targets in the field and in the laboratory will be highly correlated.

3. The search times required by O's in the field and in the laboratory will be highly correlated.

4. Distant and most extremely concealed targets will be more difficult to acquire than nearer and less concealed targets both in the field and in the laboratory.

2. Methods and Procedure - Field Tests and Laboratory Projections

Efforts to implement each of the aims and objectives outlined above will be described in this section.

2.0 Test Sites - Selection and Properties

No naturally occurring single test site could possibly be representative of all military environments on earth. Still there are common visual properties to earth, stone and foliage to be found anywhere. The Lexington, Virginia environment might best be described as representative of the temperate-zone mountain-and-plain mixture with a variety of leaf cover including conifer and deciduous trees. Since tanks and trucks were deemed desirable targets the test site had to be able to accommodate them. It happens that the Army ROTC armor contingent at the Virginia Military Institute maintains an 80 acre area less than 3 miles from the school. In cadet training exercises, tanks and trucks are maneuvered there year round. Hence, the site was readily accessible to the bank of observers, and could be set aside for uninterrupted experimental use for the duration of this field testing period in the spring and summer months of 1976.

To explore the implications of the decision to employ two different types of target location and three different observation distances for each location, several pilot trials were made. These trials showed that two hill top sites could best be used--one at the extreme westerly end of the total tract and one some 300 meters east of the center of the rectangular tract. Total elevation extremes of the area in question is less than 30 meters. With judicious placement of observation posts it was possible to avoid having more than one post of the three in each direction in violation of the eye-level viewing criterion (see the photographic illustrations below). Presence of trees, mostly juniper, pine, oak and poplar prompted post and target locations based on a compromise of the desired distance dimensions. For example, the targets for both directions had to be located as much as 100 meters difference in distance from the observer at a given post.

This means that the distances from observer (O) to target are averages for the three different targets. The most distant single target was some 900 meters from the observer post, while the nearest one was situated about 300 meters away. In subsequent sections, reference is made to distant (1A, 2A), intermediate (1B, 2B), and near (1C, 2C) target placements. It should be kept in mind then that each of these posts represents a range of distances between 0 and the targets, for the rolling terrain prohibited precise standardization of this variable. To provide visibility of the targets and especially the howitzer, a careful repositioning of observation post and targets was required before observations could be initiated at each post.

Perhaps the brief catalog or summary of direction and distance below will be helpful to the reader who wishes to conceptualize the terrain and the organization.

Mean Observation Post Distances in Meters

	1.	(looking west toward Allegheny Mountains)
Far	1A	900 + or - 60
Intermediate	1B	600 + or - 50
Near	1C	350 + or - 25
	2.	(looking east toward Blue Ridge Mountains)
Far	2A	800 + or - 60
Intermediate	2B	500 + or - 60
Near	2C	300 + or - 60

The same data are expressed graphically in the field test layout shown in Figure I.

For perspective, then, the target distances varied between a full half mile at one extreme and about 500 feet at the other with some 16 different target distances in between these two extremes, depending again upon the six post-target distances, three in each direction. MERDC and VMIRL personnel agreed upon the two sites prior to any testing effort.

2.1 Targets

Again, the selection, preparation and placement of reasonable numbers of representative military targets was arrived at by collaborative

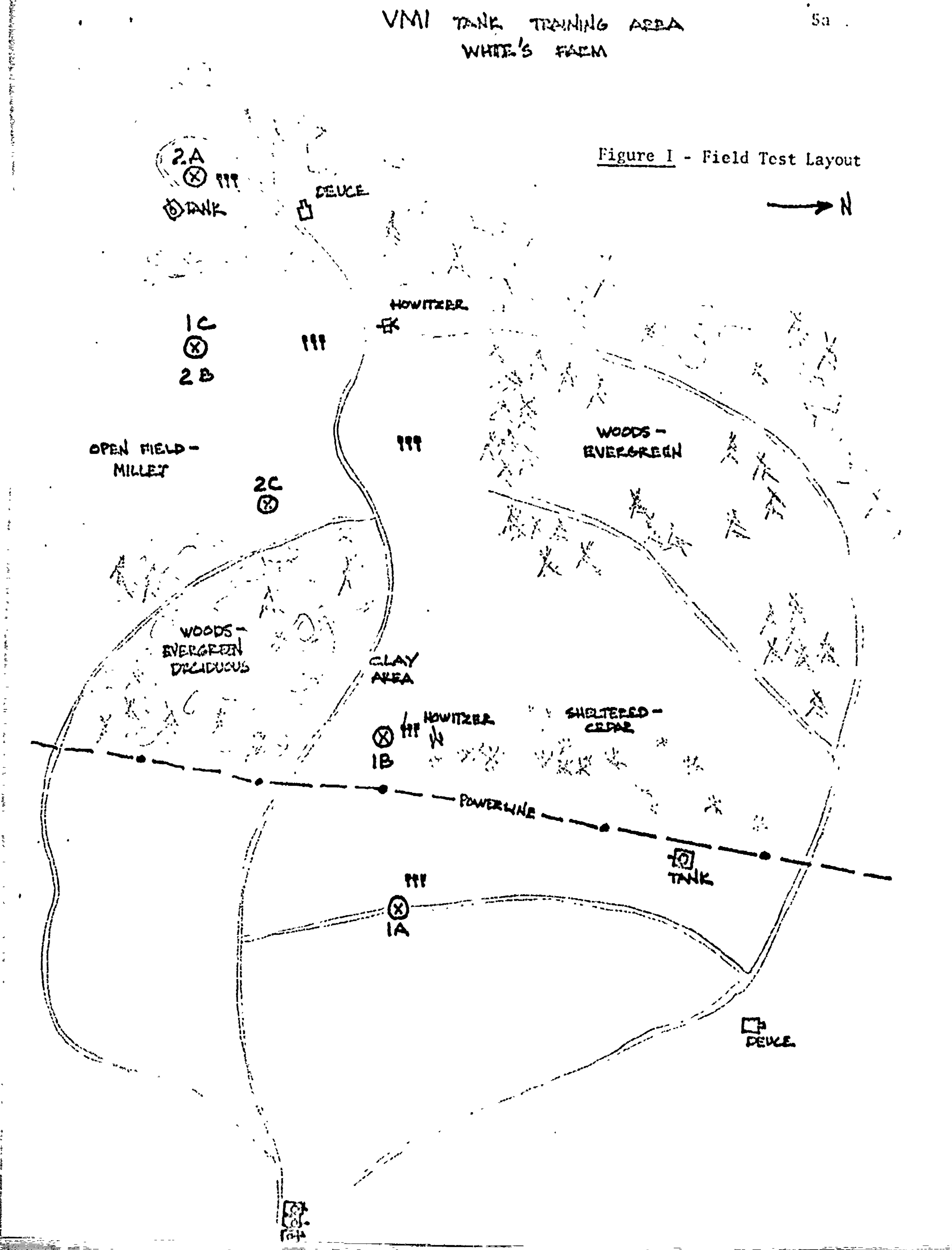


Figure I - Field Test Layout

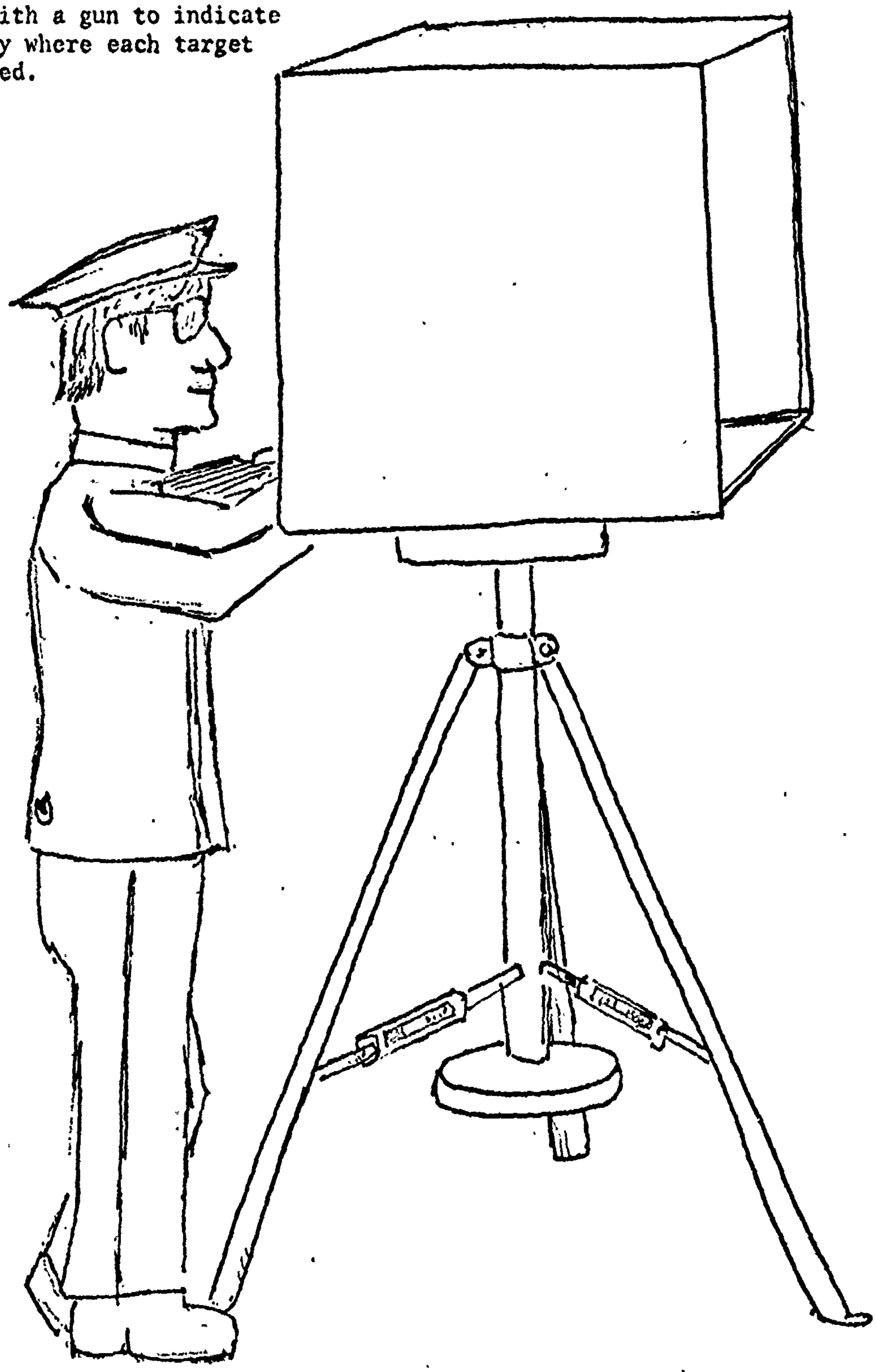
efforts of MERDC and VMI staff members including ROTC personnel. MERDC specified the camouflage painting procedure and supplied the paint. There may be statistical advantage to the placement of only one target per site since, in a timed search, observers are necessarily slowed by each detection and identification. Nevertheless, it became apparent that such potential disadvantage would be outweighed by the advantages of obtaining greater quantities of data at each site by increasing the number of targets on each test range. Accordingly, three targets were selected--all of them familiar modern implements employed in combat: a tank, a howitzer, and a 2-1/2 ton (duce and a half) truck without canvas cover.

Ideally, the percentage exposure of each target would be rigorously controlled, e.g., 20% of each of the three in view on one site and 50% at another. But practical considerations prevented such nicety of control and for several reasons. Tree leaves and branches when blown reveal less or more of the target moment by moment. Also, daily repositioning of these large targets made precision of placement and standardized angle of exposure impossible. Therefore, we we e forced to settle for approximations and assume that the photos were representative of the average field exposure. See Appendix IV for colored photos of all slides.

2.2 Subjects

Volunteer VMI cadets with normal vision (no weakness of color reaction, and acuity of 20/20 or better) were transported to the field test range prior to actual performance. They were instructed in the nature of the task at the test stand (see Appendix III for standardized instructions), timers were started, and the search began. With all subjects

Figure II - A test stand which confines the observer's view to 90 degrees directly in front of him. After all targets have been found, he points with a gun to indicate precisely where each target is located.



the search continued for three minutes, for no subject knew that there were three and only three targets. Hence, they believed by implication that the scene might have, say, three or more howitzers or two trucks. This kept them searching and sighting false targets, but it also may have increased the number of detections. Incidentally, with the more than 100 observers in the field and over 200 in the laboratory every one seemed to serve at very high motivation levels.

2.3 Measuring Acuity

All observers had been subjected to tests of their vision relatively recently in their ROTC assignments. Still, each was rechecked for acuity in the field with a series of clusters, of three objects per cluster, of differing height and distances. The number of acuity clusters differed with the topography, for in many areas visible open space was non-existant in which one might place the clusters. Each object was a cylinder 8" tall and 6" in diameter. They were permanently mounted on the top of wooden stakes after target acquisition was complete. O was asked to locate as many cylinder clusters as he could, and then to state which of the three was tallest and shortest, and which was nearest and farthest away in each cluster.

Incidentally, in the laboratory the conditions were always constant and a field test of acuity was not indicated. Therefore, every observer was tested on a short form of the Bausch and Lomb orthorater with three stereoscopic displays: right eye, left eye, and stereopsis to yield Snellen data from 20/10 to 20/400 and adequate or inadequate stereopsis.

2.4 Test Stand

A very heavy wind resistant--all-weather test stand was built for use at all six posts in the field. See illustration below of the test stand on a typical observation post in Figure II. Its base is a tripod of 2" pipe with adjustable legs (by turnbuckle from a weighted suspended center). A one hundred pound disc for balance was anchored to the platform table and suspended six inches above the ground. Thus the tripod could be placed on any terrain up to a 20° slope with the platform or table always level and at constant height of forty eight inches. On the table an open 3' cube closed on 4 sides was bolted. It had an opaque curtain on the side opposite the observer. Inside the cube an air rifle was mounted on a bearing such that the observer could sight out and "shoot" each target after his search time was complete. The cube therefore served the purpose of restraining O's field of view to a horizontal and vertical 90°; it permitted timed search--and it housed the means for checking O's accuracy in the field.

In the laboratory, the test stand consisted of a chair positioned squarely in the center of the screen at 7' distance, where, exactly as in the field (except that the rifle was replaced by a light pointer), O searched a 90° field of view with the geometrics of the field matched as closely as possible by the 7' O-to-screen distance. For details, see Figure III of the laboratory layout.

2.5 Photography

The objective of the photographs was to reproduce about 90° of the scene in which the targets had been situated. Camera properties limited the field to about 86° or less, the total viewing angle depending upon

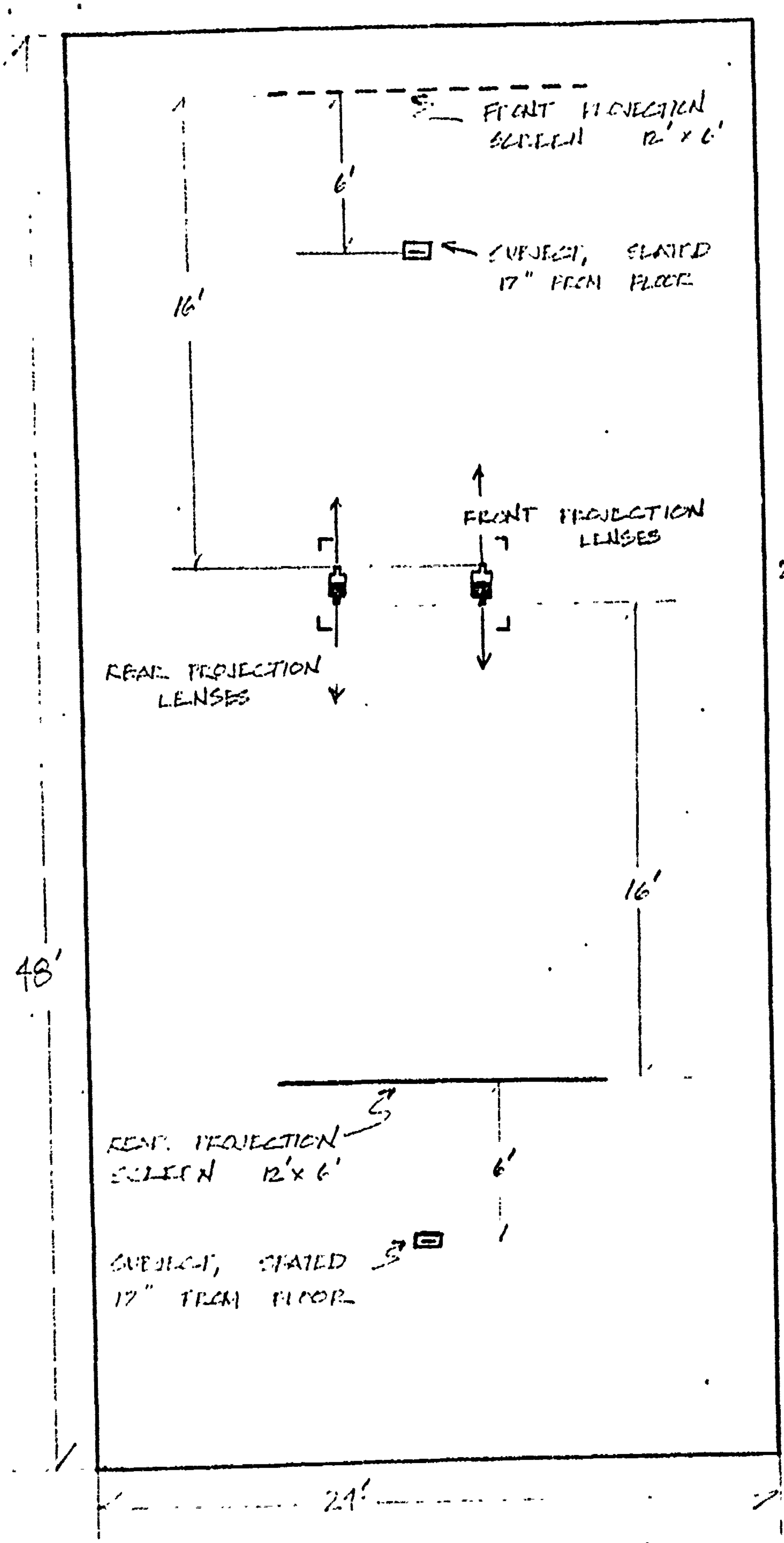
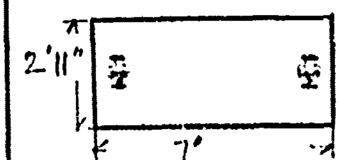


Figure III - Laboratory Layout



PROJECTORS PLACED WITH LENSES ONE FOOT FROM EDGE OF PLATFORM FACING SCREEN, AND CENTERLINE OF PROJECTORS ... ITS' PERPENDICULARS SIX INCHES FROM LEFT OR RIGHT EDGES, FIVE FEET FROM FLOOR.

SCALE: 3/16" = 1'

the accuracy of the camera sighting of a chosen midpoint which served as the extreme side. The camera selected for use: Pentrax Model Hla. Camera Lens: Super Takumar 1:2/55 mm, 43° angle of view. The film: Kodak Kodachrome 25 daylight transparency. Film exposure determined with light meter, typically, 1/125 second. Additional shots were made at 1/4 stop intervals to give an experimental range of exposures at 1/2 stops either side f 5.6. Cable release and very sturdy tripod prevented camera movement during exposure. Since only one camera and one tripod were employed, both shots at each post were taken from the same position. This option saved moving the camera to a different point some 6' to the side of the first photograph, thus separating the shots by the same distance as they would appear on the screen. But O scans the scene from the very place that the two shots were taken. Literature guidance on panoramic photography is rare, if it exists. We were unable to benefit by the experience of others in this phase. Hence, we were forced to a prior use of a midpoint reference object and a slight overlapping of scenes for trimming later.

The brochure by Eastman Kodak plus numerous other references cited below were of material help, including Klaiber's (66) report on projection techniques. Early on, the importance of illumination, sun angle, atmospheric conditions, film, and other variables was recognized and every attempt was made to select a time and condition most proximate to the mean state of the field of view at each test stand when O's were in action. The photographs below, which were printed from the slides actually used in the tests, and double mounted as in the panoramic projection, illustrate target positions and the total scene searched by O's at each of the six posts. They cannot begin to portray in a

3" x 5" reproduction the clarity of detail and the reality proximation of a 4' x 12' panorama in full color.

2.6 Projection

A totally darkened laboratory 30' x 65' was chosen as a theater for simulation display. (See scale layout in Figure III.) Two new Leitz projectors, model #31-636, were selected as the best matched pair of a batch of a dozen in a single shipment. Nevertheless, image matching of the panorama had to be effected by attaching a voltage regulator between one of the projectors and the current supply. Though Leitz supplied a test target, it is insufficient in size or character for valid registration of the capacities of projectors, accuracy of focus, interprojector balance or the numerous other film-projector screen and distance dimensions which significantly affect image quality. Accordingly, with each two-part scene the experimenter, working with assistance, was able to adjust focus and light intensity of the two projectors so that: (a) the bipartite image appeared to be a single scene and, (b) that all parts of the entire double projection were as uniformly representative of the original (real-world) scene as possible.

Not only would superior standardized and complete test slides be useful for this type effort, but so too would additional calibrators for objective assay of image quality. It is all too apparent that test validity depends upon the properties not only of the individual elements of equipment which produce the image, but also upon the interactions among them. Nevertheless, in the laboratory maximum effort was made to provide as many constancies as possible. For example, as shown in the layout, a special projection table was constructed and placed in fixed position on the floor such that the height and separation of the projectors assured constant centering of the respective halves of the screen. This table was located in the center of the theater so that it would serve both the opaque and rear view screens.

2.7 Phototransparencies, 35 mm, color slides

To assure constant focus of projection, a dimensionally invariant material, glass, was employed for mounting the slides. At the same time and prior to glass mounting, the two images had to be cropped so that during projection the bipartite field appears unified. Such cropping is facilitated by magnification, so the film trimming was accomplished with the aid of a microscope.

Again, the film of choice was 35 mm Kodachrome-25 reversal transparencies, developed by Kodak and quality across all transparencies appeared uniformly high. In fact, very close study of the projected images reveals th , the grain of the film is apparent and that the limiting dimension of this variable does not adversely affect the images in question.

2.8 Opaque, or Front, and Translucent, or Rear View, Screens

Most prior work on screen construction and quality of images had concentrated upon black and white displays. Objective methods are rarely employed, or where they appear, the final judgment on screen quality is at best "artistic" or freely subjective. To select an optimum screen of both types, therefore, required adherence to a similar procedure, yet we were guided by Klaiber's, Dryer's, and other reports. Samples of alternate choices were assembled and pilot tests run. We found wide differences in the resulting image quality. It is obvious that projection screens are not a commodity of interchangeable qualities. Our selection process, therefore, involved relative judgment across screens by a sampling of observers. The screen samples were unmounted and small, and projection conditions were quite unlike those to be employed in the subsequent tests. Hence, the choices might have been quite different had we had access to full-sized mounted screens, additional samples, and superior conditions for testing.

The final choices were Polocoat flexible rear projection screen and a DaLite flexible front projection screen. The mounting of these 6' x 12' screens is important in order to assure a fixed flat surface at a uniform distance from the two projectors. Therefore, we fabricated identical frames into which both materials were mounted. These frames were made of 1" tubular steel to which a 3/8" iron rod was welded slightly inboard of the tubes. Thus a trussed strength and rigidity are achieved and at the same time a yielding support at the centers, which keeps the ties in constant tension. The screens (provided with spaced eyelets) are secured to the frame with nylon rope which was continuously laced around the rod for the entire periphery much like a trampoline. Each frame was suspended from the ceiling with three cables and locked in place to prevent any screen movement. The two metal frames worked exceptionally well in this application and with pulley provision could be pulled up to a safe position at the ceiling when not in use.

2.9 Data Collection

The handling of response information required only conventional methods which are described in the results section below. The same observer response form was used in field and lab. Data analysis involved only straightforward correlational methods plus procedures for analysis of differences in means. Our intention at the outset was to use decision theory approaches and let the data dictate when sufficient numbers of observers had responded. But, it soon became apparent that the cell sizes in each of the 6 x 5 matrix could not be treated in this way. For example, some responses could not be counted, but this fact was never known in advance, and for reasons beyond the control of the experimenters. Though infrequent, a sudden change in illumination could void the efforts of an observer, as could his misunderstanding of instructions. One O identified some 20 targets in his three minutes of search time. Every time his gaze came upon a target, no matter how many times he had already detected it, he called out again, "tank," "truck," "tank," etc.

Therefore, the N's in each cell vary more than is convenient to process. Ideally, all should have had a fixed number, say, 16 or 25 per post or cell. The ideal is rarely realized. But in spite of this variation between the number of O's per post, all data appear to be sufficient for the test objectives.

After several pilot trails, a workable data sheet was evolved (see data sheet in Appendix). It specifies the O's name, times, range, visual acuity, target acquisition, correct and false detects and the cues to detection, both correct and false. But these cues, it should be pointed out, are taken after O pointed to whatever target (or artifact) to which he was responding. Only thus could the experimenter record the cues appropriately as correct or not.

3. Results

3.0 Detection, An Overview

Let us recall that the data collected from field and laboratory observations address this question: Can a photographic film duplicate the real-world accurately enough to provide observers with the same problems of object detection and identification which they experience in the actual three dimensional scene? Hence, we seek to determine the correspondence in operational detection of targets located in real and simulated environments.

Recall, too, that in every scene three targets are located as follows--an armored vehicle, a wheeled vehicle, and an artillery piece.

As a first general data summary, note the table below.

TABLE I - MEAN PER CENT DETECTS OF THE THREE TARGETS

Target	Field	Front Projection	Rear Projection	Average
Tank	83.6	81.5	74.0	79.7
Truck	45.9	52.3	48.5	48.6
Howitzer	56.2	47.5	59.9	54.8
Average	61.9	60.5	60.6	61.0

These averages demonstrate rather surprising agreement in that they vary less than two per cent in mean detection between field and either projection.

But have the averages obscured the variances involved? To answer this, let us be reminded that 3 targets located at three distances on two different test ranges and shown on 2 types of screen yields a total of 18 x 3 or 54 key data points. Thus, let us examine the greater detail evident in the second table (Table II). Herewith from examination we can identify certain inconsistencies. For example, consider 2BT where the rear view projection reduces the visibility of the tank, whereas for 2CH the rear view screen enhanced the howitzer's possibility of being detected. Nevertheless, thorough inspection suggests that large deviations are relatively rare and this is confirmed by statistical treatment as we shall see later.

TABLE II - RANK ORDER OF PER CENT CORRECT DETECTION (D) FIELD AGAINST LAB

Legend: 1-Woodland, 2-Meadow; A-Distant post, B-Intermediate, C-Near; T-Tank, D-Duce & 1/2, H-Howitzer

Target	Field	Front Proj.	Q	Rear Proj.	Q	Ave. Proj.	Q
1CT	100	86	3	100	0	91.1	3
1CD	100	86	3	100	0	91.1	3
1CH	100	71	6	100	0	81.5	4
2AT	95	73	5	88	3	79.3	4
1BT	94	94	1	100	0	97.3	0
2CT	86	100	0	80	2	91.2	1
1BH	69	88	0	100	0	94.7	0
2CH	67	74	1	93	0	82.4	0
2BT	65	76	0	22	6	48.2	3
1AT	62	60	0	53	1	56.3	1
1BD	56	56	2	80	0	69.3	0
2AD	55	60	0	27	3	39.1	3
2BH	50	12	3	11	4	11.5	3
2BD	35	59	0	50	0	54.4	0
2AH	27	0	2	12	2	7.6	2
1AD	24	53	0	35	1	43.4	0
1AH	24	40	0	41	0	40.5	0
2CD	5	0	0	0	0	0.0	0
Average	61.9	60.5	26	60.6	22	61.0	27

$P\ (Q \leq 26) = .00002$
$P\ (Q \leq 22) < .00001$
$P\ (Q \leq 27) = .00003$

Table II listed the results in rank order of per cent detections (d) in the field. Therefore, this mixes the targets and posts in an array that may be hard to follow. A rearrangement of the same data is presented in Table III where inspection of rows and columns free of any special ordering or averaging may permit a clearer view of the correspondences between targets at the three distances across methods of viewing. Thus it can be seen that the howitzer is a little more difficult to see in the field than on the screen at the greatest distance of 1A. But the opposite is the case in 2B where this gun is more apparent by far in the field than in the laboratory. However, a quick glance at the duce-and-a-half truck reveals that on that same site, 2B, it is more readily evident on the screen than in the field. Then, and also at 2B, the front and rear projection detections differ on the two screens. But most other data are in better agreement.

So another summary table which might be pertinent at this point is a depection of the relative success of the observers at each post on each target. See, then, Table IV showing correct detections at each post. Most O's correctly detected 2 targets, the next largest group found only 1, followed by three, and only 36 or about 12% of 290 O's could find or correctly detect any targets at all.

In these first five tables we have sought to highlight differences in detection which may arise from difficulties in any of the independent variables including instructions to the observers. Still, are all these differences sufficiently significant to call the method of simulation into question? The answer is statistical (correlational) in nature. Let us therefore proceed to the rationale of our analysis after which we will then illustrate the products of the analyses. First, let us examine briefly Table V which adjusts times to detect correctly for all targets at all posts. No detects are counted as 180 seconds.

TABLE III - PER CENT OF OBSERVERS DETECTING EACH TARGET AT EACH POST

		Tank	Howitzer	Duce
1A	Field	62	24	24
	Front	60	40	53
	Rear	53	41	35
1B	Field	94	69	56
	Front	94	88	56
	Rear	100	100	80
1C	Field	100	100	100
	Front	86	71	86
	Rear	100	100	100
2A	Field	95	27	55
	Front	73	0	60
	Rear	88	12	27
2B	Field	65	50	35
	Front	76	12	59
	Rear	22	11	50
2C	Field	86	67	5
	Front	100	74	0
	Rear	80	93	0

	Most Distant (1A + 2A)	Intermediate (1B + 2B)	Near (1C + 2C)	Average
Field	48	61.5	76.3	61.9
Front	48	64.1	58.3	60.5
Rear view	42	60.5	78.8	60.6
Average	46	62	71	

TABLE IV - NUMBER OF OBSERVERS MAKING 0-3 CORRECT DETECTS AT EACH OF SIX POSTS BY ALL THREE VIEWING METHODS FIELD, FRONT, AND REAR PROJECTION

Meters	Post	N	0	1	2	3
800-1000	1A LF LR	21 15 17	8 3 4	7 5 6	4 3 5	2 4 2
500-600	1B LF LR	16 16 20	0 0 0	2 1 0	8 8 4	6 7 16
200-300	1C LF LR	5 7 4	0 0 0	0 2 0	0 0 0	5 5 4
900	2A LF LR	18 15 26	1 2 3	5 6 15	9 7 6	3 0 2
500	2B LF LR	20 17 18	4 2 7	5 7 7	7 6 4	4 2 0
250	2C LF LR	21 19 15	2 0 0	6 5 4	12 14 11	1 0 0
TOTALS 101 89 100		 Field Front Proj. Rear Proj.	36 15% 9% 14%	83 25% 29% 32%	108 40% 41% 30%	63 21% 20% 24%

TABLE V - NUMBER OF FALSE DETECTS AT ALL POSTS COMPARING FIELD WITH LABORATORY BOTH FRONT PROJECTION (FP) & REAR PROJECTION (RP)

Post	Site	N	Tank	Duce	Howitzer	Total
1A	Field	21	8	6	9	23
	FP	15	8	7	15	30
	RP	17	8	7	14	29
1B	Field	16	0	1	5	6
	FP	16	3	2	6	11
	RP	20	6	6	5	17
1C	Field	5	0	0	0	0
	FP	7	0	0	0	0
	RP	4	0	0	0	0
2A	Field	18	2	8	12	22
	FP	15	7	5	13	25
	RP	26	8	4	4	16
2B	Field	20	6	15	8	29
	FP	17	5	9	11	25
	RP	18	11	5	12	28
2C	Field	21	8	11	9	28
	FP	19	1	6	14	21
	RP	15	4	4	10	18

TOTALS	#O's	View	False Detects
	101	Field	108
	89	Front	112
	100	Rear	108

Per cent of O's could not be used, for some observers contributed several (as many as 5) false detects, while other observers at all sites made no false detects.

TABLE VI - (T_1) RANK ORDER OF TIMES TO CORRECT DETECTION OF TARGET AT EACH SITE WITH NON-DETECTS COUNTED AS 180 SECONDS, BUT WITH AVERAGE TIME COMPUTED BY DIVIDING TOTAL DETECTION TIME BY THE NUMBER OF O'S WHO MADE A CORRECT DETECTION. Q IS THE NUMBER OF "INVERSIONS" OF ORDER.

Target	Field	LFP	Q	LRP	Q	LFP & LRP	Q
1CT	8.4	78.5	4	40.3	2	64.6	4
1CD	8.8	71.3	3	10.0	0	49.0	1
1CH	24.4	153.0	5	58.8	2	118.7	4
1BT	37.0	46.3	1	25.6	0	34.8	0
2AT	39.1	128.9	3	107.2	3	115.1	2
2CT	69.7	36.7	0	87.8	1	59.2	1
1BH	115.8	54.6	0	58.7	0	56.9	0
2BT	125.8	118.5	0	707.8	7	421.6	6
2CH	142.8	153.3	0	105.9	0	132.4	0
1AT	149.8	1(2.6	0	225.6	1	196.1	1
2AD	215.3	216.7	1	598.3	4	458.7	4
1BD	221.7	229.6	1	123.4	0	170.6	0
2BH	278.5	1398.0	3	1512.5	4	1456.9	3
2BD	412.7	175.4	0	231.3	0	204.1	0
2AH	551.0	00	2	1469.7	2	00	2
1AD	631.6	237.1	0	389.2	1	317.9	0
1AH	637.8	307.2	0	336.9	0	323.9	0
2CD	3720.0	00	0	00	0	00	0
			23		27		28

TABLE VII - (T_2) RANK ORDER OF TIMES TO CORRECT DETECTION OF TARGET AT EACH SITE WITH NON-DETECTS COUNTED AS 180" AND AVERAGE COMPUTED BY USING ALL O'S. Q AS "INVERSIONS" OF ORDER IN THE PAIRED RANKINGS.

Post & Target	Field	FPQ	Front	Rear	RPQ	Avg. FP & RP	Avg. Q
1CT	8.4	4	67.3	40.3	2	57.5	4
1CD	8.8	3	61.1	10.0	0	42.5	1
1CH	24.4	6	109.3	58.8	2	90.9	3
1BT	34.7	1	43.4	25.6	0	33.5	0
2AT	37.3	3	94.5	94.8	2	94.7	2
2CT	59.8	0	36.7	70.2	1	51.5	0
1BH	79.7	0	47.7	58.7	0	53.8	0
2BT	81.8	0	90.6	157.3	6	124.9	4
1AT	92.7	0	97.5	119.4	2	109.1	1
2CH	95.2	1	112.9	98.9	1	106.7	0
2AD	117.4	4	130.0	161.0	4	149.7	4
1BD	124.7	3	129.1	98.7	0	112.2	1
2BH	139.2	3	164.5	168.1	3	166.4	3
2BD	144.4	0	103.4	115.7	0	109.7	0
2AH	150.2	2	180.0	169.6	2	173.4	2
1AD	150.4	1	126.5	137.4	0	132.3	1
1AH	151.9	0	122.9	138.7	0	131.7	0
2CD	177.1	0	180.0	180.0	0	180.0	0
		31			25		26

3.1 Statistical Analysis - Rationale and Description

For each target we used three statistics to measure the "search difficulty" of the task.

The first of these statistics is, d, which is the percentage of subjects that could detect the target within 180 seconds. These data have been displayed in Table II.

If we assume the detection time for any particular target has the exponential distribution

$$f(t) = \begin{cases} 0 & t<0 \\ \theta e^{-\theta t} & 0 \le t \end{cases} \quad , \theta \ge 0$$

then we would like to estimate the mean detection time, $E[T] = \theta$. However, this is complicated by the fact that no detection times are recorded for subjects who failed to detect the target within 180 seconds.

If out of n subjects k of them detected the target in 180 seconds and they have times $t_1, t_2, \ldots t_k$ then one may show that the maximum likelihood estimation for θ is

$$T_1 = \frac{1}{k} \sum_{j=1}^{k} t_j + \frac{(n-k)}{k} (180)$$

(See Kendall and Stuart, 1969, for a fuller elaboration of the derivation of this equation.)

We computed T_1 for each target. However, it has been shown that

$$VAR(T_1) \sim \frac{\theta^2}{k\left(1-e^{-\theta(180)}\right)} ,$$

(See Deemer and Votaw, 1955.)

Therefore, when we have difficult targets the variance of our estimator, T_1, is very large because the true mean detection time, θ, is large and the number of subjects who detect, k, is small. In fact in the laboratory there were two targets where k=0. In this case T_1 is not defined.

To avoid such an undefined value we employed a different analytical procedure, yet one consistent with the detection-time logic outlined earlier. So, we shifted to the closely related statistic

$$T_2 = \frac{1}{n}\left\{\sum_{j=1}^{k} t_k + (n-k)180\right\}$$

still measuring the "search difficulty" of the target. That is, we used a detection time of 180 seconds for each subject that did not find the target just as with T_1 but the denominator includes all of the observers whether or not they detected a target correctly. If all O's correctly detected, therefore, $T_1 = T_2$.

After calculating all three statistics for each of the eighteen targets seen in the field, we ranked each series by the degree of "search difficulty" as measured by each of the three methods. Then, the same 18 targets were shown in the laboratory by front projection and they were ranked by "search difficulty" using the same methods as in the field. This same procedure was followed when the targets were shown by rear projection. (See Tables II, III and VII.)

We compared the ranking in the field with the rankings in the laboratory by two methods. First we counted the number, Q, of "inversions" of order.

For example, suppose there were five targets and we found that their rankings compared as follows:

1st in field = 2nd in lab

2nd in field = 3rd in lab

3rd in field = 1st in lab

4th in field = 5th in lab

5th in field = 4th in lab

We need only consider the sequence 2, 3, 1, 5, 4.

There are three inversions of order, 2-1, 3-1, and 5-4. Therefore Q=3.

If our laboratory ranking of target difficulty is consistent with our field ranking, we would expect Q to be very small.

Since we have 18 targets ranked in the laboratory we have 18! possible rankings. We wish to test the null hypothesis that our laboratory rankings are independent of our field ranking. Under that null hypothesis, each of the 18! rankings would be equally likely. Under this assumption we may calculate the probability distribution of Q. (See Kendall and Stuart, Volume 2, page 477-480.)

We also calculated,

$$r_s = 1 - 6 \frac{\sum_{i=1}^{n} (d)i^2}{n\,(n^2-1)} ,$$

This is the conventional Spearman's rank correlation coefficient. With it we also compared the field ranking versus lab, front projection ranking, and the field ranking versus lab rear projection ranking.

Again under the null hypothesis it is possible to calculate the exact distribution of r_s. In fact for n = 18

$$P\ (r_s \geq .625) = .01$$

It can also be shown that for large n

$$t = r_s \sqrt{\frac{n-2}{1-r_s^2}}$$

has the "Student's" distribution with n-2 degrees of freedom.

3.2 Treatment of Results

We obtained the following results:

TABLE VIII - SIGNIFICANCE OF DETECTION PER CENT & TIME-TO-DETECT METHODS

	Method of ranking	Number of inversions	$P(Q \leq q)$	r_s	t	students 16df $P(T \geq t)$
Field vs lab FP	d	26	.00002	.8230	5.795	Less than .0005
	T_1	23	Less than .00001	.8633	6.842	"
	T_2	31	.00016	.7745	4.897	"
Field vs lab RP	d	22	Less than .00001	.8467	6.636	"
	T_1	27	.00003	.8328	6.018	"
	T_2	25	.00001	.8349	6.068	"
Field vs. weighted avg. of LFP and LRP	d	27	.00003	.8251	5.8416	"
	T_1	28	.00005	.8137	5.599	"
	T_2	26	.00002	.8535	6.5516	"

$$P\ (r_s \geq .564) = .01$$

Using any of the three measures of "search difficulty" we may consider the following model:

$(T)_{ij}$ is the "search difficulty" (T_1, T_2, or d) of the j th target (j=1,2,3,...18) under test condition i (i=1,2,3). Where i=1 is the field test, i=2 is the lab front projection method and i=3 is the lab rear projection method.

We assume

$$(T)_{ij} = \mu_i + \beta_j + e_{ij}$$

where μ_i is the contribution due to the test being run by the ith method (field, LFP, or LRP). βj is the contribution due to the target (size, color, distance, etc.). e_{ij} is a random component which we assume to be normally distributed with mean zero and variance σ_i^2.

For each measure of "search difficulty" we wish to test $H_0: \mu_1 = \mu_2$ against $H_1: \mu_1 \neq \mu_2$ and $H_0: \mu_1 = \mu_3$ against $H_1: \mu_1 \neq \mu_3$. That is, we want to answer the question:, "Is there a difference in search difficulties due to the method of presenting the target?"

If we pair observations by targets we have

$$D_j = (T_{1j} - T_{2j}) = (\mu_1 - \mu_2) + (e_{1j} - e_{2j}).$$

Therefore under the null hypothesis we see that D_j is normal with mean zero. Therefore as we have 18 targets, $t = \frac{\bar{D}_j}{S_{\bar{D}}}$, has the "Student's" distribution with 16 degrees of freedom.

We found the following:

TABLE IX - ANALYSIS OF SIGNIFICANCE OF DIFFERENCE IN MEANS BETWEEN FIELD AND BOTH LABORATORY (L), FRONT (FT), & REAR (R) PROJECTIONS

	Measure of search difficulty	$\bar{D}$	$S_{\bar{D}}$	Students t	df
Field vs. LFP	d	1.444	4.540	.318	16
$H_0: \mu_1 = \mu_2$	T_1^*	-28.03	81.667	-.343	14
$H_1: \mu_1 \neq \mu_2$	T_2	-12.183	8.258	-1.475	16
Field vs LRP	d	1.222	4.927	.248	16
$H_0: \mu_1 = \mu_3$	T_1^{**}	-142.282	99.955	-1.423	15
$H_1: \mu_1 \neq \mu_3$	T_2	-12.506	6.935	-1.803	16

*target 2AH and 2CD could not be used in this case because there were no detects in the lab, and therefore T_1 could not be calculated.

**target 2CD could not be used because there were no detects in the lab.

Now $.05 = P(|t|>2.120)$ at 16 df;

$.05 = P(|t|>2.131)$ at 15 df;

$.05 = P(|t|>2.145)$ at 14 df.

Therefore we find no evidence to reject H_0 at even the 5% significance level.

Under ideal conditions there should be a linear relation between the search difficulty of a target presented in the field and the search difficulty of the same target presented in the laboratory.

Using per cent detect and T_2 to measure search difficult we fit a least square regression line to our eighteen targets.

We obtained the data displayed in Table X.

The t values given in that table are used to test the null hypothesis that the slope of the regression line is zero. Under the null hypothesis t has the students distribution with 16 degrees of freedom. Therefore, we easily reject that null hypothesis at the .1% significance level.

TABLE X - REGRESSION ANALYSIS OF TARGET DETECTION PERCENTAGES AND TIMES TO DETECT WITH SIGNIFICANCE OF EACH

Methods of Proj.	Measure of "search diff."	Regression equation	Correlation product moment	Per cent of variance accounted for	t
Lab front vs. field	% det d	$d_{L_f} = (.801)d_f + 10.854$	.797	.635	5.282
	T_2	$T_{L_f} = (.614)T_F + 48.190$	.766	.587	4.704
Lab rear vs. field	% det	$d_{L_r} = (.993)d_f - .795$	.820	.671	5.733
	T_2	$T_{L_r} = (.824)T_F + 28.921$	.850	.722	6.514

4.0 Discussion of Results

The major objective of this study was to learn whether or not camouflage effectiveness can be validly measured without having to take military observers out to the field. Our results answer in the affirmative. This is not to say that human observers can be replaced in target detection tasks. Instead, these results show that observers can function in the laboratory just as effectively as if they were actually on location in the field. The methods employed were straightforward and conventional in that readily available photographic and projection systems were employed. Target acquisition behavior was also conventional and the findings permit standard analysis of observer accuracy and speed of detection. Thus a comparison has been completed of observer performance in the real world with the performance of comparable observers responding to a photo simulation of that same real world scene. Again, the data in the form of correlation analysis defend the conclusion that the simulation employed is valid.

Let us briefly review the data in question. Tables I through V summarize the responses of more than 300 observers (100 in the field, 100 responding to front projection and another 100 to rear view projection). Three different targets set at three different distances from the observer on two terrains produced a total of eighteen data points. Inspection of these tables reveals that correct detection rates, and even the number of false detections are similar in the laboratory to the field performances. Then in Table VI the correlational analysis begins, continuing through Table X, all of which serve to indicate highly significant positive correlations between laboratory and field acquisition behavior. In fact, the correlations are significant at the .001 confidence level and beyond.

This degree of correlation, it should be noted, obtains from two different non-parametric methods (Kendall and Spearman, rank order) and also by a least square regression procedure. All show that on both % detected (d) and time to detect (T_2), both front and rear projections are significant at beyond the .1% level.

We see then that by chance there is much less than one chance in 1000 that the field and laboratory data are randomly related. Furthermore the rear view and front projection systems in the laboratory also march in step. Specifically on times to detect, as an example, the Spearman rank correlation is +.81, which is quite similar to the magnitudes shown in Tables VIII and X. This is not surprising in view of the equivalence of individual and combined screen correspondence with field performance and is mentioned only in the interests of presenting a complete correlational analysis, and with the scattergrams in mind (Figures IV, V & VI).

The correlation is encouraging in that it substantiates the employment of a readily accessible type of simulation, but signs of relationship do not in any sense explain what accounts for the coincidence between field and laboratory performances. It might be helpful, therefore, to examine some of the dimensions which contribute to the findings observed herein. In most general terms, the properties of most direct concern are threefold: (a) target perception which in turn involves the act of seeing and discriminating; (b) visual acuity and the measurement of individual differences in ability to distinguish objects in the environment; (c) the simulated scene differs from the real world largely in that it presents only two dimensions rather than all three. Let us briefly discuss each.

Figure IV - Scattergram Averaging Front and Rear Projection and Comparing with Detection in Field

FIG IV

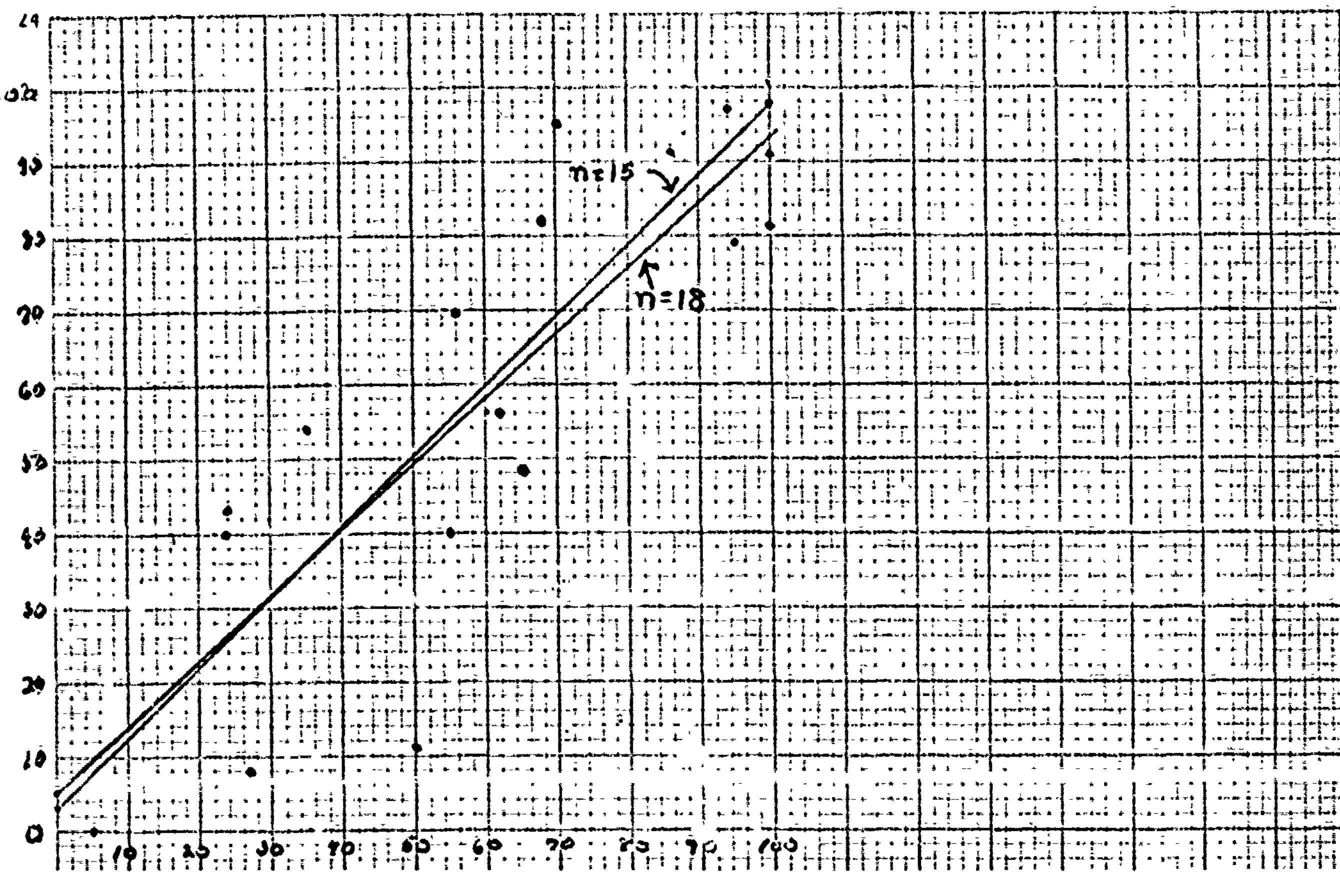


Figure V - Scattergram Comparing Rear Projection with Field Detection

FIG. V

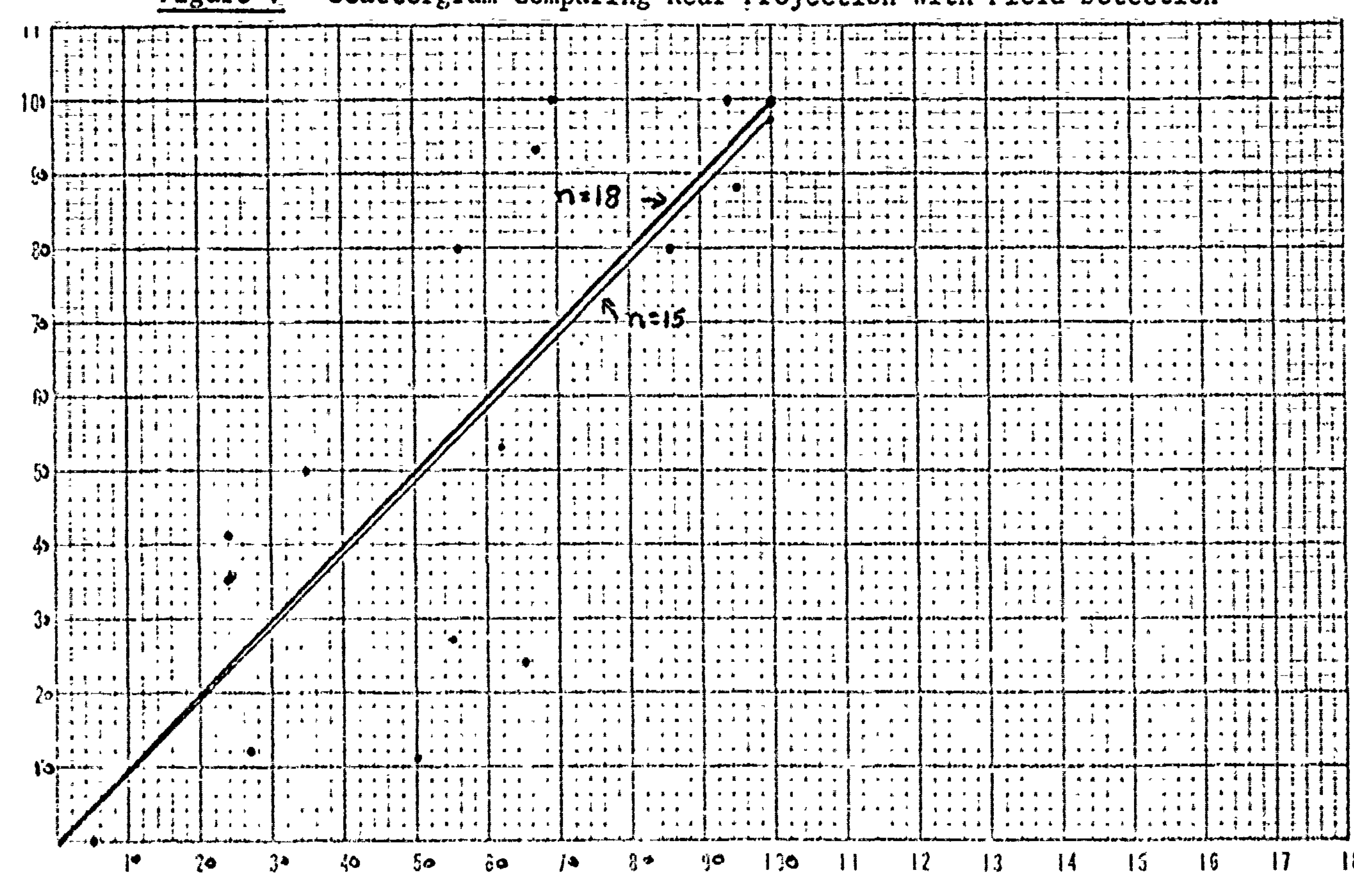
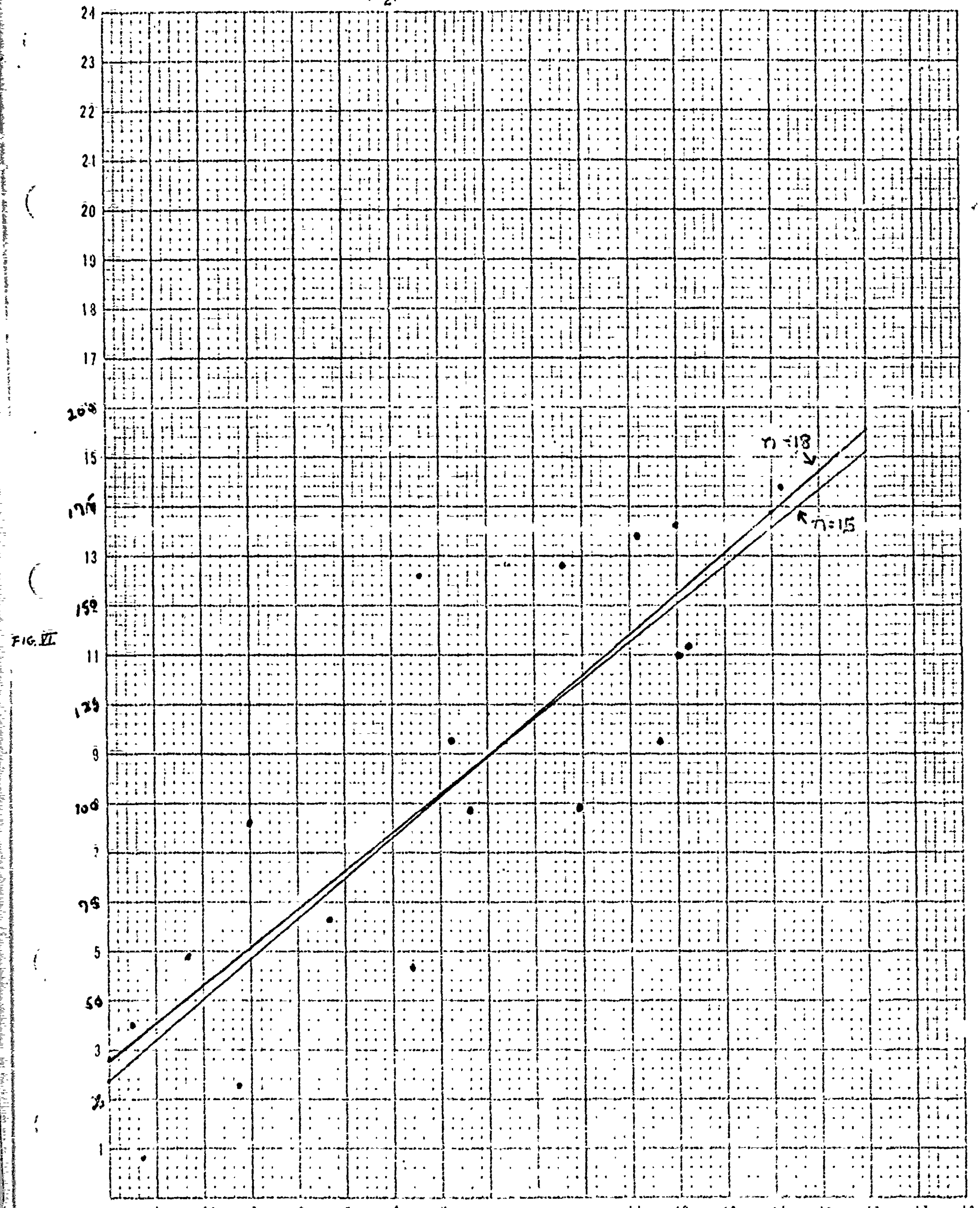


Figure VI - Scattergram of Laboratory Rear Projection (T_2) vs. Field (T_2)



Target detection or acquisition has been extensively studied and numerous reports are available on the cues that contribute to target or object perception. Attneave (1950, 1957, 1959), for example, stresses the importance of contour, outline, symmetry, angles and the complexity of the form. Boersma (1969) demonstrates the key part played by eye movements in the apprehension of embedded figures. Corso (1967) and Dodwell (1970) discuss the diverse nature of the many parameters contributing to object detection and identification including relative brightness, luminance, contrast, color, size, and the like. Hoke (1966) gives an intensive overview of the physical properties of the stimulus which contribute to perception. Johnson and Meyer (1973) present data on the large individual differences in ability to identify a target in a complex background. These and related reports indicate that a diverse series of target properties aid O in detection and recognition. Nevertheless, for present purposes of comparing field with simulated environments, all such variables that were extant in the field were assumed to operate also in the photo projections. In other words, no attempt was made to isolate particular independent variables as to relative importance to detection. This does not mean that O's were not asked to list the cues. The protocols record every statement made by O as to the cues he received for detection. But the point is that no pattern of cues emerged. Shape, color, brightness, shadows, contrast, etc., but many of the "cues" were nouns "gun shape," "turret on top" or "looks like a truck." Obviously O's, thoroughly familiar with the targets sought, were object oriented and were therefore unprepared to abstract out the details of sensory input which dominated the target acquisition (or the false detects either).

Secondly, we were greatly concerned with the optical acuity of each O. In the field, and since our observer population is subjected to regular and relatively frequent visual examination, each O reported his latest acuity data and whether his vision is corrected or not. A 20/20 minimum was required for participation with or without spectacles. But one cannot avoid a skeptical attitude about the validity of office measure of acuity when the object is detection of targets in a "busy" field which extends many times as far as the oculist can provide for in his office. Hence, it is conceivable that a sample of 20/10 O's might detect significantly fewer targets than, say, a 20/20 group or even a 20/30 group of the same size and motivation. For this reason, we attempted without full success to arrange a field test of acuity (described under the method above), designed to check especially vernier acuity (see Corso, 1967). The limits of visual discrimination under ideal circumstance are reported to be less than 1 second of arc as the smallest resolvable angle. But when are conditions ideal? Many reports state that to detect irregularities in the contour of an object requires a nominal minimum of 40 seconds of arc (Gibson, 1966, and Cornsweet, 1970). Still, in the field or in the laboratory, acuity measures did not predict O's performance. Nor did the special cylinders employed for checking the resolving power of the individual O's eyes. Logically, we wanted to be assured that if, say, a distant telephone wire was visible in the field that it would be equally visible in the photo projection. The ideal then would be to find a method of assaying acuity in the field and in the film independently of the targets. But, in lieu of more analytically differentiating stimulus patterns for acuity measurement, the targets perhaps served in and of themselves as a practical answer to the problem. But such a statement can be made only because of the highly significant correlations. If lesser correspondence had been obtained, a superior calibration would have been essential to understanding.

Finally, and in view of the positive correlation between the behavior in the full three dimensional real world, and to the flat surface screen having only two linear dimensions. What are the crucial differences? First, O's task does not require stereoscopic or depth or binocular perception. One eye, therefore, in this type of target detecting might be nearly as good as two. And perhaps a sketched tank or howitzer shape on the slide would have served as well as the actual reproductions of the tank, truck, and howitzer. Recall, too, that with the typical interocular distance of about 65 mm and the acuity limits mentioned earlier the stereoscopic resolving power approaches zero at about 40 seconds. So at less than 400 meters, stereoscopic vision cannot provide O with any additional information. Fraser, 1966, states that for most practical purposes stereopsis is of real value only for distance judgments up to about 30 feet. But again O is not making a distance judgment. Instead he is seeking a special regularity or irregularity of shape, a darker or lighter patch, a break in color, or a contrasting property in which actual position in the y dimension is inessential.

And so the common sense desire to add depth to the simulation or to correct for the lack of it is not warranted. The findings reported here suggest that a static display of high reproductive quality in two dimension though it be of monoptic genre is quite adequate. In actual viewing, and perhaps especially with the large panoramic scene which occupies so much of the total visual potential, the eye tends to respond as if the scene receded past the screen. Thus there is minimum distraction from the flatness (see Kling and Riggs, 1971). Nevertheless, to achieve the appropriate total angle of regard of about 90°, O is situated just 7' from the screen and squarely in the center of the screw. The laboratory room was darkened which reduces visibility of the surrounding stimuli which normally give clues for proper focusing of the eye. Thus focus on the two dimensional surface is indeterminate. In any case, in other experiments where different stimulus materials are used the flat screens might, for any of the reasons cited, turn out to be a handicap, but it did not serve adversely here.

4.1 Discussion of Some of the Problems

In the course of these experiments as with any such investigations, certain difficulties emerged. They include:

1. Test patterns could not be found to assist in the systematic and objective selection of: (a) camera, (b) film, (c) projectors, and (d) opaque and rear view screens. The literature (Dreye, 1969, Heath, 1969, Dreyer, et al, 1970) is replete with generalized information but products change as do the demands of the moment. Manufacturer's literature was readily procured, but standard test patterns for field and laboratory equipment evaluation are not available. Such patterns may have to be devised. In principle they should permit simple quantitative assessment of such key variables as lens properties, film resolution, color fidelity, and image properties across the field.

2. Visible size of each target is not only difficult to control in the field, but it also resists accurate measurement in the laboratory. As a first approximation, we simply sketched an outline of each target on

a sheet of graph paper placed on the rear view screen. Then by counting the mm squares, approximate target size was ascertained. Average tank size was found to be 183.2 sq. mm's, the truck 175.6, and the howitzer 103.5. This is roughly in accord with their actual sizes, but the range of visible surface available to O's search ranged from 20 to 405 mm^2.

Quite a large variation indeed! No better solution was found. Ideally; one would hope for an automatic optical method for scanning each target from O's position and registering the sizes in sq. units, degrees, or other geometric dimensions. The same desire might apply to contrast, reflectance, color, and contour, but these other variables would seem to be more complex than visible size. The point is that no satisfactory method was found for this measurement.

3. Color slides fade with continuing projection. When informed, the manufacturer stated that after one hour fading is noticeable. Also, all photo dyes known are faded by the energy of light in the visible part of the spectrum. The present experiments require several hours of projected exposure. Most applications of photo transparencies are for brief periods only, so the problem rarely comes up. How to work around it? Making copies of the slides turns out to be a very poor solution indeed. Therefore, all one can do is make extra identical photographs in the field, discarding each after one hour of projection.

4. Panoramic display of two slides with two projectors is taxing, especially in mechanical preparation of matched slides and in conjunctive projection. Obviously, one larger slide of the conventional 3-1/4" x 4" size will accommodate the two 35 mm slides. This was tried, but the meeting edges doubled the altogether too visible vertical line down the center. A special panoramic camera and/or a film merging technique

may solve the problem in the future. Again, no help could be found in any of the literature.

These four problems are illustrative of the technical difficulties encountered in these attempts to achieve most valid simulation. By implication each suggests a special investigation focused upon the finding of practical solutions for each. Another problem will be presented in the recommendation section below.

5.0 Conclusions

The findings in the present study justify these conclusions:

1. Special photo simulation of the countryside possesses an abiding verisimilitude as measured by observer behavior. In other words, observers are no more nor no less successful at detecting targets in the real world than they are in detecting them when looking at photo transparencies displayed pancramically on either an opaque or a rear-view screen. The statistical correlation between field and laboratory target detection is positive and is significant beyond the .001 level of confidence.

2. Rear view and opaque (front view) screens are equivalent for purposes of this simulation. Observers are able to detect as many targets and as quickly on one type screen as on another, and they are positively correlated with each other.

3. Detection per cents and times to detect are equivalent measures of target acquisition difficulty and the correlation of field with laboratory data from these two measures are similar in significance.

4. This photo method is as effective at large target distances of about 1000 meters as it is when targets are located either at one half or one fourth that distance from the observer.

5. Photo simulation is equally as effective in heavily wooded terrain as it is in relatively open land.

6.0 Recommendations

We can only urge that color photo projections have demonstrated their practical value for target concealment-detection applications. Therefore, they should be considered for replacement of the more expensive field observation of targets of all kinds. In short, the present study indicates that the photo method can readily be applied where one wishes to develop or test methods for concealing equipment or personnel.

Not only is it easier to send one photographer rather than, say, one hundred observers out to the field, but in many ways he can do a superior job. For example, he can take repeated shots as personnel or equipment are moved to different angles or positions with differing light angles, cover, and background. Observers are readily biased by exposure or by too much information. Not so the film for it can be shown in the laboratory under controlled conditions to any types of observers desired.

All of this urging of practical application of the method is not to argue against additional field-lab correlation studies, especially if air-to-ground or movement of either targets or observers is indicated. But for conventional ground-to-ground acquisition work the case would seem to be made for this approach.

We are encouraged to make one additional recommendation for development of a quantitative assessment technique which was a by-product of this investigation. If successful, it could greatly reduce the number of observers required for target detection in the laboratory. In essence, the proposed method would convert target detection from a psychometric to a psychophysical procedure.

Specifically, one should expect that a graded masking energy will eliminate the detection possibility of some targets much easier than others. Using the appropriate masking stimulus and psychophysical methods, it should become apparent that 3 to 5 people could replace 20-25 observers without loss of validity or precision of results.

This last recommendation for additional refinements is to supplement those advanced above under 4.1, Discussion of Problems, section in which new test patterns, target size measurement methods, and superior film-slide preparation were recommended for consideration.

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APPENDIX I - A Note on The Literature Search & Development of a Bibliography

The development of a bibliography is motivated by the desire to build upon the findings and insights of prior workers who have contended with related or similar endeavors. Specifically, the present study is concerned with such problems as these: camera-film color reproduction of natural scenes; projection techniques; panoramic scene projection; slide preparation; information display; camouflage technique; measurement of camouflage effectiveness; visual search; target detection and recognition; target acquisition; pattern recognition; visual masking; target parameters as determinants of detection potential (e.g., color, contour, contrast, size, detail, position); simulation and perception; visual acuity, psychometric and psychophysical methods; experimental design; statistical analysis.

One of the initial sources employed was the collection of pertinent handbooks and reference texts asterisked in the bibliography. Next, we examined the camouflaged bibliographic library at MERDACOM, and upon finding very few perceptual citations, we requested Defense Documentation Center Defense Supply Agency reports under such key words as: projection, simulation, photography, and camouflage. The least productive term in that group was "simulation", for this concept extends into fields too remote from the present investigation. Nevertheless, some 20 abstracts on the term "projection" alone were procured. About 500 papers were found on projection, simulation and photography. Similarly other relatively recent studies were requested on camouflage and the like. These were studied. The *Psychological Abstracts* lead to many other resource publications. The combination of DD, abstract, and works referenced in the primary and handbook sources led to inclusion of a few pertinent resources in the references.

Directly relevant materials formed very small per cent of the references examined and are thus not included in the bibliography. In other words, the number of references could have been multiplied readily to an unwieldy length, but future workers in this area would not stand to profit by inclusion of incidental, tangential, and irrelevant literature. So, the majority of citations are to the point of the present effort.

APPENDIX II - Pilot Studies - Here is a brief summary of six of the more influential preliminary or pilot studies performed before and during the course of this investigation.

I. Photography - The problem was to determine how to take and how to project two (panoramic) slides. Paired polaroid shots of an outdoor scene, followed by projection was effected in order to determine the utility and value of a centering object to guide the photographer. A vertical object to "split" the right and left side of the view-finder was tried so that overlap or missing portions could be avoided. Also, we tried to test different means of projection as to avoid overlap, studied use of special cutting of the edges of each scene to cause them to meet exactly without lapping. Two stereopticions (3-1/4" x 4" slides) were employed showing that overlap of scenes can produce very distracting effects of additive luminescence as can other scenes which in panorama do not appear to be unified as they would be in a single photograph.

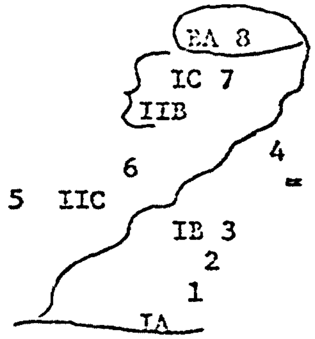
II. Projections - A comparative study of a series of 35 mm projectors including a sampling of those which were being used by the V.M.I. art, physics, and biology departments, each of which had need of high resolution or undistorted projection of a variety of slides. Two Ektagraphic carousel projectors were purchased, but balance could not be achieved and optical properties were questionable. Major manufacturers and sales representatives were consulted, and with their guidance, purchase had been made upon a consensus. But test patterns are unknown or too specific (e.g., black & white) for valid testing of screen or projector qualities. Additional projectors were purchased as a matched pair and balanced by voltage regulation of one of them. This phase of the visual display art seems to be primitive, yet much superior projectors may be extant.

III. Slide Making - Study of ways to mount 35 mm color slides to achieve a match of two slides placed in two projectors and the images positioned on a screen to produce the effect of a single slide. Cutting of edges under a microscope is too tedious, slow, and expensive of effort to be practical. Accordingly, a second study was made of a common mounting of two 35 mm slides cut by a 35 mm editing cutter and mounted in conventional glass lantern slides (3-1/4" x 4") for lantern projection with different focal lengths and various projection differences. The hypothesis that one, not two, projectors for panorama appears valid if the mating edges were not so distractingly visible as a dark line. Glass mounts appear to be essential for focus maintenance, but moisture inevitably collects inside.

IV. Field Measures of Acuity - Study of methods for measuring visual acuity in the field that would be visible as a self-calibrating measurement of the subjects (observers), illumination, cameras, films, projectors, projection distances and the like. (See table below showing all distances.)

We see in a special Navy publication ("The Effects of Pattern and Color on the Visual Detection of Camouflaged Vehicles" by Hubert O. Whitehurst) that acuity and target acquisition are highly correlated.

Hence, we placed standard size objects at various locations in each scene--the objects being in proximate clusters of three varying in x, y, z coordinates. Illumination and visibility varies across a 1000 meter scene with and without changes of sun angle. The objects used were three dimensional: 8" x 6" round cans mounted on 3' wooden poles driven in the ground. These objects changed reflectances with each change in position of sun or cloud or observer. A much more effective permanent series of



Observation posts looking West IA
Observation posts looking East II, acuity clusters 1, 2, 3.
Each can for acuity measurement is 6" in diameter & 7" tall,
all mounted about 3' above ground, and in trial about 12' across.

# of Acuity Cluster		Distance in feet	Distance in meters	1 Minute of Arc in inches	Correct tallest	In inches	Correct shortest	Correct farthest	In inches	Correct nearest	In inches
IA	2	294	90	.615"	L	3.5	C 1.5	R	90	R	24
	6	850	259	2.96"	L	1.5	R or C15	C	12	L	48
	4	1350	411	4.71"	R	3	L 7	R	48	C	12
	7	1750	533	6.10"	L	2.5	R 4.5	L	72	C	72
	8	2450	747	8.55"	L	3	C 4	L	60	C	78
IB	4	863	263	3.01"	R	3	L 5	R	48	C	12
	6	1025	513	3.58"	C	1	L or R1	C	12	L	48
	7	1225	373	4.28"	C	1.5	R 6.5	L	72	C	72
	8	2075	633	7.24"	L	6	C 7	R	18	C	60
IC	8	800	244	2.79"	L	6.5	C or R6.5	R	18	C	60
IIA	7	738	225	2.57"	C-R	5.5	L 4.5	C	72	R	72
	3	2013	614	7.03"	L	6	C 1	L	53	C	15
	2	2188	667	7.63"	R	6	L 3.5	R	22	L	73
	1	2475	754	8.64"	R	2	L 6	C	72	R	72
IIB	3	1200	366	4.19"	L	3.5	C 2	L	53	C	15
	2	1438	439	5.01"	R	3	C or L3	R	22	L	78
	1	1662	507	5.80"	C	3	L 3.5	C	72	R	72

IIC (not yet measured)

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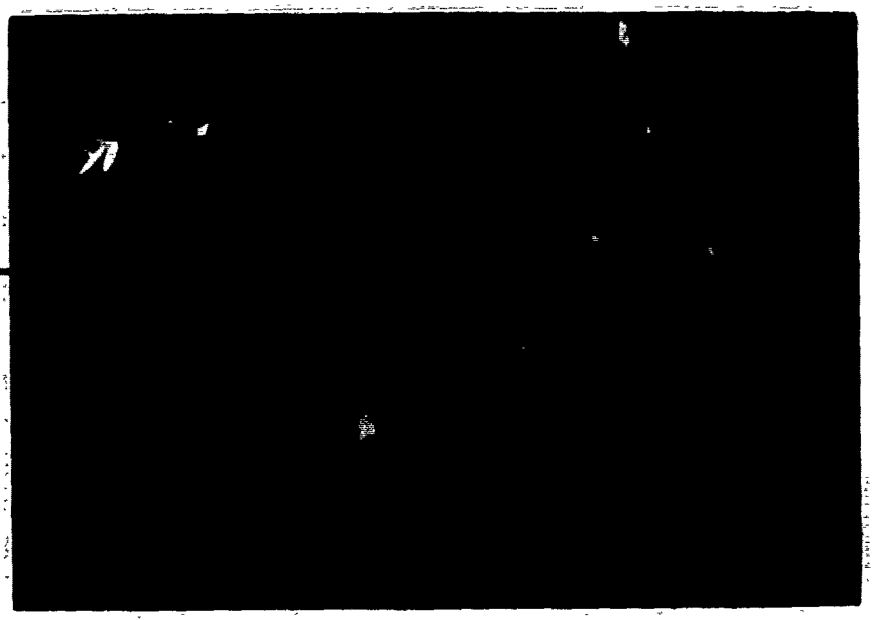
calibrators for positioning at fixed distances from the observers and the camera should be designed for such studies.

V. Scaled Down Model Forest - A study of reduced scale simulation of various terrains, foliage, and illumination was effected to facilitate the development of key parameters in a controlled environment. It is shown in the photographs below.

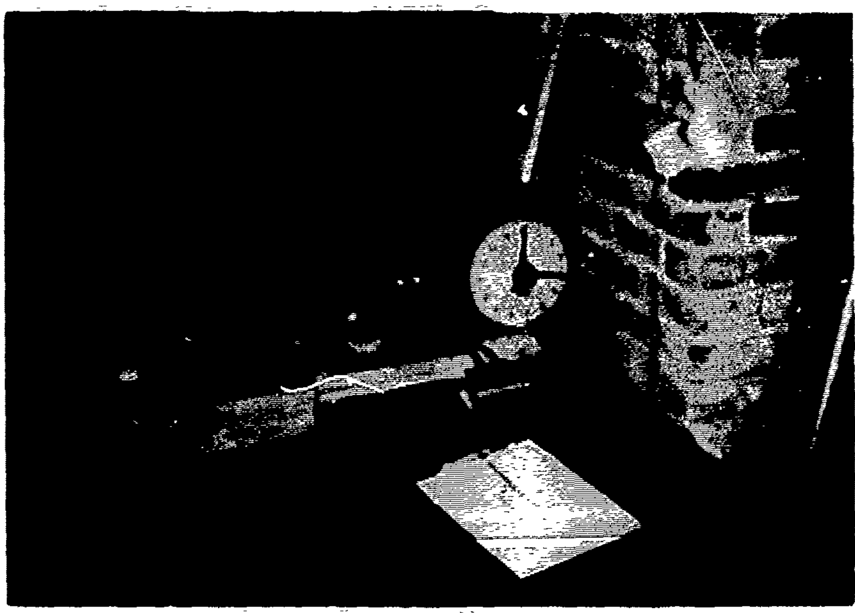
An indoor site was equipped with a 20 to 1 scale reduction of trees, bushes, stones and targets on a dirt floor, 60' x 20', with a 14' ceiling. Special lighting was arranged in five banks of incandescent spots concealed in the ceiling at 15 foot intervals. Both conifers and deciduous trees were "planted" in the ground to form a convincing simulation of a forest. Exact scale models of the same three targets used in the study were given camouflage treatment and were placed in different degrees of concealment much like the field condition described in the present report.

In this model, instructions, guns, illumination effects, target placement and other variables were pre-tested before moving to the field. Photos of this scaled down scene were taken and projected also to give us a feel for the problems which might be faced in the subsequent series. (See colored photographs below.)

VI. Masking Targets - Given that photo transparencies yield a valid simulation accurate enough to produce the same behavioral reactions to targets as one finds in the real world, then when factors contribute most to target detection? One can change a variable of focus, illumination, color or brightness contrast, anything, but this reduces to an abstract exercise in atomistic description. Instead, one needs a means for effectively assessing the ease--difficulty continuum with firm reliable



Scaled down model (20 to 1) of a woodland terrain in which three targets are located at the simulated distances of 250,500, and 1000 meters. Actual small cedar (juniper) and oak branches were placed in the clay earth with four banks of adjustable incandescent lights to control angle and amount of illumination.



Light and time control panel for scaled down laboratory shown above.

gradations. In short, one sought a psychophysical method for occluding and clearing the target. In preliminary study we tried many approaches, the simplest being onion-skin paper on the rear view screen. One target was still visible through 26 sheets of onion-skin paper. Another disappeared when only 18 sheets were laid flat against the rear of the screen. Intuitively, a spotlight of graded intensity appeals, but no adequately accurate means of control was found.

Next we acquired a series of neutral density filters, but the members of the series have large steps between them. A lens system provides the possibility of a linear series for continuous adjustment. A camera shutter over a spotlight was tried. We wished to avoid tachistoscopic exposures. All of these methods were tried without finding the optimum method.

When it is developed, the number of observers in camouflage studies could be greatly reduced and with no sacrifice in validity or reliability if all other parameters are carefully maintained.

DATA SHEET . (Please check answers)

Os Name ____ Last ____ First ____ Initial ____

1. Test range #1___, #2___
2. Field test ___, Lab test-front projection ___, Lab test-rear projection ___
3. Subject #___ Is subject's vision corrected? Yes___ No___
   If yes, indicate 20/___ right; 20/___ left
4. Subject to target distance: Far___, Middle___, Near___

RESPONSE:

1) Response time _____ seconds; O reported it was a: T H D (circle)

Correct detect___, False detect___, Correct identify___, False identify___

Cues to correct detect: ____________________

____

Cues to false detect: ____________________

____

2) Response time _____ seconds; O reported it was a: T H D (circle)

Correct detect___, False detect___, Correct identify___, False identify___

Cues to correct detect: ____________________

____

Cues to false detect: ____________________

____

3) Response time _____ seconds; O reported it was a: T H D (circle)

Correct detect___, False detect___, Correct identify___, False identify___

Cues to correct detect: ____________________

____

Cues to false detect: ____________________

____

4) Response time _____ seconds; O reported it was a: T H D (circle)

Correct detect___, False detect___, Correct identify___, False identify___

Cues to correct detect: ____________________

____

Cues to false detect: ____________________

____

5) Response time _____ seconds; O reported it was a: T H D (circle)

Correct detect___, False detect___, Correct identify___, False identify___

Cues to correct detect: ____________________

____

Cues to false detect: ____________________

____

Numbers of acuity test clusters seen ______

	Tallest	Most Distant		Tallest	Most Distant
Nearest trio	L C R	L C R	Fourth	L C R	L C R
Second nearest	L C R	L C R	Fifth	L C R	L C R
Third	L C R	L C R	Other	L C R	L C R

APPENDIX III - Instructions

I have agreed to participate in this experiment being conducted by the VMI Department of Psychology to the best of my abilities. Further, to prevent contamination of experimental results, I will not discuss any aspect of this study with any person before September 30, 1976. I realize that these experiments are being conducted solely for purposes of helping the Army develop more effective camouflage methods.

The Task

The targets are a howitzer, tank, and truck (duce and a half). These targets must be located in a scene as quickly as possible within a 3 minute time limit. Don't stop looking until time is called and search the whole scene. Keep looking because you may find more targets.

Later, we will ask you to point to or "shoot" toward and identify each target. We will also ask you to tell us what cues gave each target away when you detected it, so try to remember.

ASK ANY QUESTIONS NOW.

APPENDIX IV

On the following two pages are six color photo reproductions of each test site described in the text above (pages 4 forward). This small size reproduction virtually eliminates the possibility of perceiving the targets even though a small circle has been added around a more obvious one.

The major difference in these panoramic slides is the distance from targets.

Without actually seeing the amplification of size accomplished by projection up to 4'x12', the reader may have difficulty in appreciation of the relatively high detection rates achieved by the observers.

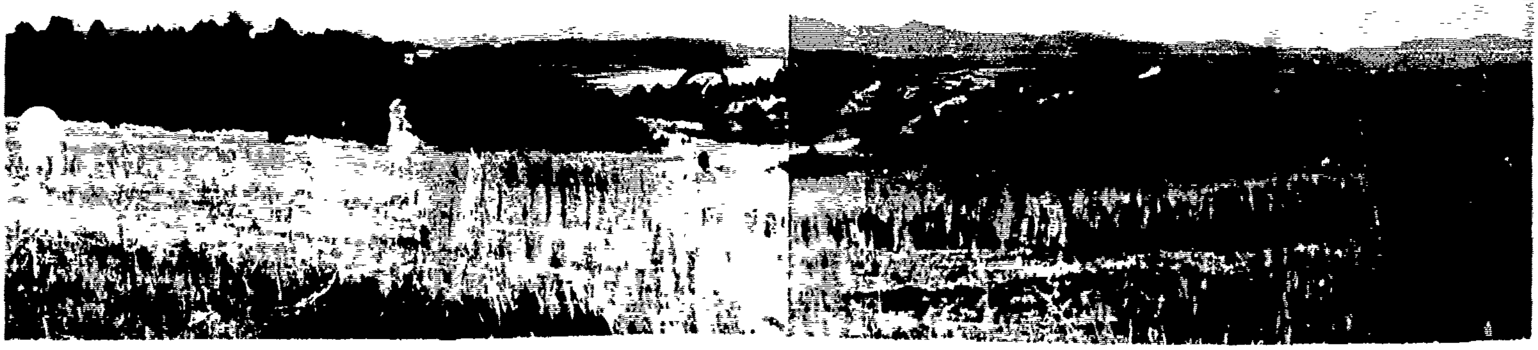
Again, these reproductions are included as an indication of the terrain, foliage, and distances.

1A 800 to 1000 METERS - LOOKING WESTWARD TO ALLEGHENY MOUNTAINS

1B 500 to 600 METERS - LOOKING WESTWARD TO ALLEGHENY MOUNTAINS

1C 100 to 250 METERS - LOOKING WESTWARD TO ALLEGHENY MOUNTAINS

2A 800 to 1000 METERS - LOOKING EASTWARD TO BLUE RIDGE MOUNTAINS



2B 500 to 600 METERS - LOOKING EASTWARD TO BLUE RIDGE MOUNTAINS

2C 100 to 250 METERS - LOOKING EASTWARD TO BLUE RIDGE MOUNTAINS